Litigation and Solicitor- Client Privileged and Confidential

PROTECTED - SENSITIVE

Root Cause Analysis (RCA)

4468-00-E Rev 3

Event Title		Rev.	RCA No.
Heavy Water Leak	s.18(c) s.20(1)(c)	0	NRU - 09 - 04289
			Impact No. NRU-09-04289

[redacted]

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12. CAUSE ANALYSIS AND CORRECTIVE ACTIONS

12.1 Causal Factors:

Causal Factor 1 (CF-1): Changing Future of NRU

[redacted]

Causal Factor 2 (CF-2): Focus on Short Term Isotope Production Goals

[redacted]

s.18(b)
s.18(d)

Causal Factor 3 (CF-3): Symptom Based Problem Solving

[redacted]

Causal Factor 4 (CF-4): [redacted] Ineffective Use of OPEX

[redacted]

Causal Factor 5 (CF-5): Low Standards and Acceptance of Plant Operational Problems

[redacted]

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[redacted]

s.18(b)
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Causal Factor 6 (CF-6): Less Than Adequate Management Oversight

[redacted]

13. CORRECTIVE ACTION PLAN

The corrective action plan for this event will be developed based on the analysis contained in NRU-508760-REPT-002, NRU Vessel Leak Repair Commission Member Document for Canadian Nuclear Safety Commission Meeting, 2009 November.

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[redacted]

s.16(2)
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s.18(d)

16. ANALYSIS TECHNIQUES

Event and Causal Factor Charting

Barrier Analysis

17. INVESTIGATION TEAM

T.A. Moir – RCA Lead Investigator
C. Bromley – RCA Team Mentor
G. Arsenault – RCA Team Member, RCA SME
K. Sedman – RCA Team Member, Bruce Power RCA & Engineering SME
L. Lupton – RCA Team Member, Management Process SME
G Mark - RCA Team Member, Ops SME
C.W. Turner - RCA Team Member, Chemistry/Corrosion SME

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Appendix A [redacted]

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18(b), 18(d)

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Consequence(s) (What Happened?) (List one at a time, need not be in sequential order)	Barrier(s) that should have Precluded Event (List all physical and administrative barriers for each consequence.)	Barrier Failure Mechanism (How the barrier failed)	Barrier Assessment (Why the Barrier(s) Failed) (Identify if the barrier was missing, weak or ineffective: and why)

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Appendix B [redacted]

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5. CORROSION MECHANISM

An assessment of the corrosion has been prepared based upon:

- operating experience and the investigation into the failure of the original vessel,
- analysis of water drained from the annulus at different times over the operating lives of both vessels, and
- examination of corroded components removed from the annulus.

As discussed above, the results indicate patches of vessel-wall thinning from the annulus side, with highly localized corrosion at two sites.

The available evidence suggests that the degradation is a manifestation of the nitric acid corrosion phenomenon that has been a known degradation mechanism over the lifetime of the NRU reactor. Nitric acid forms by radiolysis of nitrogen from air leaks in the presence of water. The source of the highly localized corrosion has not been determined, and could be due to changes to the wall material, making it more susceptible to corrosion, or a locally more aggressive water chemistry, for example, due to crevice conditions or the presence of impurities. In either case, the primary agent for corrosion is believed to be nitric acid.

The interim corrosion assessment has undergone third party review by two independent experts. They both agreed with the assessment of degradation broadly being due to the presence of nitric acid. They also offer possible mechanisms for enhancing the local-corrosion rate.

To further understand and potentially determine the mechanism for the localized corrosion, preparations are being made to cut out a section of reactor wall (called a coupon) where there is localized corrosion. Examinations can then be undertaken to characterize the material condition, and to characterize the chemistry and morphology of the corrosion front. The final decision on removing the wall section is predicated on there being an acceptable method for sealing the resulting hole. Development of a tool and procedure to weld a plate over the hole is being finalized.

5.1 Corrosion Coupons

Shortly after the second vessel was installed in 1974, coupons were hung in the annulus to provide information on corrosion. These coupons consisted of rods of the aluminum alloy used for the vessel, and they were suspended at three elevations (upper, middle, and lower) at various J-rod positions. Some coupons were removed in 1989 for analysis. The remainder were removed in the early to mid-1990s and stored in the fuel storage blocks as they were impeding repair and maintenance operations in the annulus.

The examination of coupons retrieved in 1989 after nine years of exposure at J-rod position 28 revealed that only the rods placed at the lower elevation had measurable wall loss. It was suggested that this corrosion was due to radiolytically produced nitric acid and that only lower rods were affected as condensing water would have collected on the lowest rods in a string.

The pedigree of the coupons removed in the early to mid 1990s is unknown. The surface layers are likely more representative of 15 years of storage. The bulk material condition is of potential interest to today's investigation. Recent examination of these corrosion rods using transmission

8. ORGANIZATIONAL ROOT CAUSE ANALYSIS

An organizational root cause analysis has provided AECL with valuable insight into process issues and resulting actions that will provide lasting improvements and contribute to the organization's future success. Some of these same organizational causes were identified in the Talisman Report commissioned jointly by the CNSC and AECL in 2008 June. Atomic Energy of Canada Limited's management has committed to working on these issues and is making progress in several key areas.

When reviewing the organizational root causes, it is important to recognize that a complex series of events has occurred over the years, resulting in actions that sometimes differ from common industry management practices. These events mainly include changes in public policy affecting the operation and funding of Chalk River Laboratories and the planning assumption that an extended NRU outage to address maintenance issues would be taken following the Dedicated Isotope Facility becoming operational.

The NRU reactor plays a significant role in medical isotope supply (30% globally). Delays with the DIF project and its eventual cancellation in 2008 May, placed increased operating demands on NRU.

An investigation into the causes for the event have revealed the following organizational causal factors:

1. **Changing Future of NRU:** NRU's mission and planned life have changed several times over the past two decades, which has placed NRU's maintenance and condition under pressure. In 1996, AECL informed the Atomic Energy Control Board that the NRU reactor would not be operated beyond 2005 December 31. Also in 1996 the MDS Nordion Medical Isotopes Reactor (MMIR) contract was signed to have the Dedicated Isotope Facility project in-service in accordance with its terms. This contributed to a shorter-term focus for operation of NRU.
2. **Focus on Short-Term Isotope Production:** An extended outage for NRU may result in shortages in isotope supply, which makes preventative work requiring an extended outage very difficult to plan and schedule.
3. **Symptom-Based Problem Solving:** A lack of questioning attitude by AECL staff led to problems being addressed by focussing on symptoms and not by looking for root causes and extent of condition. As a result, evidence that there was corrosion of the lower vessel was not sufficiently considered (e.g., deterioration of the CO_2 header at the bottom of the annulus and visual examinations of the annulus for other purposes that showed corrosion on the vessel wall).
4. **Ineffective Use of Operating Experience:** Until recently, NRU, like other research reactors, was not considered to be part of the nuclear power reactor community. Consequently, there has been little learning from power reactor organizations.
5. **Low Standards and Acceptance of Plant Operational Problems:** When repair attempts were not fully effective, and light-water leakage persisted, it was accepted as a "normal" operating condition for NRU, and the focus was on managing the light-water leakage rather than prevention.

6. **Less Than Adequate Management Oversight:** Historically CRL management did not ensure high standards for operation and that strong barriers were in place to prevent events.

These causal factors point to certain barriers that were either non-existent or compromised, and which could have prevented the event. Having said that, the event evolved over a number of decades and the assessment is based on current standards and practices for operation. In some cases, the barriers would not have been expected to be in place at that time.

Looking at the organization, as it exists now, there have been a number of improvements introduced that address causal factors for the event. For example:

- In 2005, a Chief Nuclear Officer position was introduced and staffed to bring in utility standards and an operational focus. This has resulted in increased attention to nuclear and conventional safety, and elements of a learning organization being established.
- A Leadership Academy was implemented in 2006 to train leaders and ensure they share a common understanding of expectations and standards for operation.
- In 2007, the position of Chief Nuclear Engineer/Design Authority was created for Research and Technology Operations. This has resulted in establishing engineering programs that reflect current industry practice for supporting operations such as change control, operability evaluations, configuration management, and system/equipment health monitoring.
- Following the decision to discontinue the Dedicated Isotope Facility in 2008, the Isotope Supply Reliability Program was established to ensure that the reliability of isotope production is improved by addressing plant, process and people issues in NRU, and other facilities supporting isotope production.
- In 2008, AECL secured a trial membership in the World Association of Nuclear Operators that brings training, workshops, technical support missions, and the peer review process, all of which will help raise standards and improve practices.
- The position of Vice-President and General Manager of Operations was staffed in 2009 with an individual with broad nuclear industry experience.

The above improvements have been implemented in recent years and have been effective in addressing some, but not all aspects of the causal factors. In assessing the safety culture of today, the following organizational barriers still require further improvement:

- Accountability: Staff and management tend to not accept responsibility and to regard "best-effort" as sufficient rather than taking responsibility for achieving results.
- Standards: Standards for operation are not in-line with current utility industry practice.
- Technical Support: There is a tendency to solve issues within a work group or to under value support, rather than seek input from other work groups, or beyond AECL.
- Questioning Attitude: Staff and management can be overly optimistic, without appropriate challenging of assumptions.

Asking, "Why are these barriers weakened, or what fundamental organizational failing has these symptoms?" points to an underlying organizational cause:

The organization's culture had evolved to being complacent and unchallenging, where "bad news" was often not communicated.

With such a culture, an organization is overly optimistic, industry standards for operation may not be followed, minor events are not reported, equipment degradation may not be noticed or challenged, and work groups tend to be insular as the need for external support is not recognized.

8.1 Corrective Action Plan

To address the organizational cause for the event, it is necessary to continue to effect fundamental change in the organizational culture. Successful cultural changes are based on:

- A corrective action plan that resonates with staff, and that is focussed.
- A vigorous and intense leadership response. Constant reinforcement is required to drive the change, including raising standards and expectations, and increasing demands for a questioning attitude.
- Using a focal point to create a sense of urgency.
- Establishing observable behaviours that support the focussed action plan.
- Senior managers up to and including the executive who clearly seek out and welcome questioning and challenge as the basis for identifying threats and areas for improvement.

With this framework, the broad corrective actions for the organizational cause are:

1. Standards in equipment reliability will be improved. This will require:
    - A strong focus on equipment reliability that applies to all Research and Technology Operations facilities.
    - Good cooperation between support and operational work groups.
    - A process to ensure that the consequences of equipment problems are understood and addressed.
    - Implementation of system and equipment health monitoring to ensure conditions that may impact equipment performance are identified and dealt with in a timely manner.
2. To ensure the effectiveness of a focus on equipment reliability, the following observable behaviours will need to be promoted and reinforced:
    - high standards,
    - high accountability,
    - questioning attitude,
    - broad organizational involvement, and
    - open two-way communications.